Amendments to the Specification

IN THE ABSTRACT OF THE DISCLOSURE

Attached hereto is a replacement Abstract with markings to show amendments.

IN THE WRITTEN DESCRIPTION

Please replace the paragraphs beginning at page 1, line 11, with the following rewritten paragraphs:

A carbon material (fullerene soot) having a nanometer-sized microstructure is contained in soot prepared by vaporizing carbon by arc discharge using graphite electrodes or laser irradiation to carbon in an inert atmosphere, and allowing the vaporized carbon to aggregate through gradual cooling. As the configuration of fullerene soot, a single-wall sphere represented by C_{60}, a multiwall sphere having a small void formed therein (carbon nanoparticle), a single-wall tube contained in soot prepared by vaporizing carbon by an arc discharge using graphite in which a specific metal catalyst is mixed (single-wall carbon nanotube), and a multiwall tube in which several single-wall nanotubes are concentrically arranged (multiwall carbon nanotube: deposited on the surface of the cathode when using graphite in which a metal catalyst is not mixed) have been known.

These carbon materials are expected to find applications in new material fields. As a technology of producing these carbon materials, JP-A-2001-48508 discloses a method which includes applying a high-energy beam such as electron beams, γ-rays, or X-rays to carbon soot prepared by incomplete combustion or pyrolysis of a carbon-containing compound such as a hydrocarbon or an aromatic oil to obtain nanometer-sized graphite spheres, and JP-A-2001-64004 discloses a method which includes applying laser light to a solid carbon material such as sintered carbon in an inert gas atmosphere to vaporize carbon, suspending and dispersing the resulting soot-like material in a solvent, and collecting individual or aggregated

spherical particles to obtain single-wall carbon nanohorns. JP-A-2003-206120 discloses a method which includes applying a carbon dioxide laser beam to carbon in an inert gas atmosphere at 5 to 10 atm to produce cluster carbon heated to 1000°C or more to obtain nanographite spheres.

Please replace the paragraphs beginning at page 2, line 16, with the following rewritten paragraphs:

As a method of producing a nanometer-sized hollow carbon structure, JP-A-2000-344506 discloses a method of producing a carbon nanocapsule containing a metal particle by bringing a gas mixture containing carbon dioxide and hydrogen into contact with a transition metal catalyst containing metal particles at a reaction temperature of 450 to 750°C to subject carbon dioxide to catalytic reduction, and JP-A-2003-81619 discloses a method of producing a carbon nanocapsule with an outer diameter of 100 nm or more by supplying a raw material gas containing carbon to a glow discharge plasma generated by microwaves to decompose the raw material gas. The carbon nanocapsule obtained by the former method contains a metal in the hollow space, and the carbon nanocapsule obtained by the latter method contains a Co particle and is used to produce a recording medium by causing the nanocapsule to adhere to a disc or to confine a luminescent material or an optical material. These carbon nanocapsules do not have a completely closed space. A carbon polyhedron having a polyhedral structure in which several to several tens of graphite sheets are nested may be obtained by arc discharge (see Chem. Phys. Lett. 204. 227 (1993)). Since the carbon polyhedron does not necessarily have a hollow inner space and has a relatively small particle diameter ranging from several to several tens of nanometers, a number of substances cannot be provided in the carbon polyhedron. Specifically, a method of efficiently and stably obtaining a nanometer-sized hollow carbon structure having a large inner space has not yet been put into practice.

DISCLOSURE OF THE INVENTION

The inventors of the present invention have conducted tests and studies aiming at obtaining a nanometer-sized hollow carbon structure having a large inner space. As a result of observation of soot prepared by arc discharge using carbon electrodes and soot prepared by vaporizing carbon by laser irradiation (ablation, hereinafter the same), the inventors have found that cocoon-like carbon as shown in FIG. 1 is present in the soot, and heating the cocoon-like carbon at a high temperature in an inert gas atmosphere produces hollow carbon nanoballoon structures having various shapes such as a sphere, a gourd-like shape, or a triangular pyramidal shape as shown in FIG. 2 through self organization.

Please replace the paragraph beginning at page 4, line 17, with the following rewritten paragraph:

A method of producing a carbon nanoballoon structure according to the present invention comprises heating soot prepared by an arc discharge using carbon electrodes, soot prepared by vaporizing carbon by laser irradiation, or carbon black having a specific surface area of 1000 m^2/g or more and a primary particle diameter of 20 nm or more at a high temperature in an inert gas atmosphere.

Please replace the paragraph beginning at page 5, line 5, with the following rewritten paragraph:

According to the present invention, a hollow carbon nanoballoon structure having a relatively large closed space and a method of producing a carbon nanoballoon structure capable of easily and stably producing such a structure are provided. Since the carbon nanoballoon structure according to the present invention has a graphite outer shell, the carbon nanoballoon structure exhibits excellent ~~electric~~electrical conductivity, excellent lubricity, high heat resistance, chemical stability, and excellent chemical resistance. Since the carbon nanoballoon structure is hollow, the carbon

nanoballoon structure exhibits a low bulk density and excellent insulating properties.

Please replace the paragraphs beginning at page 7, line 11, with the following rewritten paragraphs:

The carbon nanoballoon structure according to the present invention is produced by heating soot prepared by an arc discharge using carbon electrodes (preferably graphite electrodes), soot prepared by vaporizing carbon (preferably graphite) by laser irradiation, or carbon black having a specific surface area of 1000 m^2/g or more and a primary particle diameter of 20 nm or more at a high temperature in an inert gas atmosphere containing nitrogen or a rare gas such as argon or helium. As shown in FIG. 2, hollow carbon nanoballoon structures having various shapes such as a sphere, a gourd-like shape, or a triangular pyramidal shape (triangle with three curved vertices) are obtained. As shown in FIG. 2, the carbon nanoballoon structure includes an outer shell 1 having a graphite structure which is indicated by the dark area in the TEM photograph, and an inner hollow portion 2 which is indicated by the light area surrounded by the dark area in the TEM photograph. A plurality of carbon nanoballoon structures are bonded to form a structure. These structures aggregate to form a powder in a macroscopic observation. The indicator line and the reference numerals are provided in the TEM photograph shown in FIG. 2 for convenience.

As described above, cocoon-like carbon as shown in FIG. 1 which serves as a precursor of the carbon nanoballoon structure is present in soot prepared by an arc discharge using carbon electrodes or soot prepared by vaporizing carbon by laser irradiation, as described above. As the atmosphere used to synthesize the precursor, nitrogen, oxygen, hydrogen, or a mixture of two or more gases selected from nitrogen, oxygen, and hydrogen is preferable. The precursor is obtained by an arc discharge using carbon electrodes or laser irradiation to carbon in such an atmosphere. The resulting

soot partially contains the above-mentioned carbon nanohorns. When synthesizing the precursor in nitrogen or hydrogen, the amount of soot synthesized increases. When synthesizing the precursor in oxygen, refuse such as carbon fragments mixed during synthesis can be removed to a certain extent.

The inventors have focused on the phenomenon in which the above-mentioned cocoon-like carbon changes into the carbon nanoballoon structure by heating at a high temperature, and conducted tests and studies on a carbon material which undergoes a similar phenomenon. As a result, the inventors have found that carbon black having a specific surface area of 1000 m^2/g or more and a primary particle diameter of 20 nm or more changes into a carbon nanoballoon structure having a similar structure by heating the carbon black at a high temperature in an inert gas atmosphere. Ketjenblack is commercially available as such a carbon black.

A process in which cocoon-like carbon changes into the carbon nanoballoon structure was observed using a transmission electron microscope (TEM) while changing the heating temperature when heating soot prepared by an arc discharge using carbon electrodes at a high temperature in an inert gas atmosphere. The results are shown in FIGS. 3 to 7. FIG. 3 shows the cocoon-like carbon before heating at a high temperature. A graphite sheet is not observed, and the cocoon-like carbon is solid. FIG. 3 and FIG. 1 show the same sample. FIG. 3 is a low-magnification photograph of FIG. 1. FIG. 4 shows the state after heating at 1750°C. A graphite sheet is formed as the outer shell in about 20% of the particles. The particles are still solid. FIG. 5 shows the state after heating at 2000°C. A graphite sheet is formed as the outer shell in about 80% of the particles. Some of the particles have become hollow.

FIG. 6 shows a state after heating at 2400°C. A graphite sheet is formed as the outer shell in most of the particles. Most of the particles have become hollow. FIG. 7 shows the state after heating at 2800°C. A graphite sheet is formed as

the outer shell in most of the particles in the same manner as in FIG. 6. Most of the particles have become hollow. FIG. 7 and FIG. 2 show the same sample. FIG. 7 is a low-magnification photograph of FIG. 2. Therefore, it was found that the heating temperature for obtaining the carbon nanoballoon structure is preferably 2000°C or more, and still more preferably 2400°C or more.

The above-mentioned carbon nanohorns and the like are also contained in soot prepared by an arc discharge using carbon electrodes or soot prepared by vaporizing carbon by laser irradiation. As a result of tests, it was found that a significant change in the weight of the soot did not occur before and after heating at a high temperature in an inert gas atmosphere. Therefore, it was confirmed that the carbon contained in the soot including the carbon nanohorns other than refuse such as carbon fragments mixed during synthesis completely changed into the carbon nanoballoon structure by heating at a high temperature in an inert gas atmosphere.

Please replace the paragraph beginning at page 13, line 2, with the following rewritten paragraph:

FIG. 13 shows the evaluation results of the voltage (V)-current (I) characteristics, and FIG. 14 shows a Fowler-Nordheim (F-N) plot. As shown in FIGS. 13 and 14, it was confirmed that electrons are emitted from the electron source upon application of an electric field.

Please replace the paragraph beginning at page 14, line 15, with the following rewritten paragraph:

A similar carbon nanoballoon structure was also obtained when heating soot, prepared by an arc discharge using two graphite electrodes in an oxygen atmosphere, at 2800°C in an argon atmosphere. When performing an arc discharge in an oxygen atmosphere, the amount of soot prepared was small. On the other hand, the amount of refuse such as carbon fragments mixed during synthesis was reduced. A similar carbon

nanoballoon structure was also obtained when heating soot, prepared by an arc discharge in a hydrogen atmosphere, at 2800°C in an argon atmosphere. There was no significant difference between the carbon nanoballoon structure produced by heating the soot prepared by an arc discharge in a hydrogen atmosphere and the carbon nanoballoon structure produced by heating the soot prepared by an arc discharge in a nitrogen atmosphere. A similar nanoballoon structure was also obtained when heating soot, prepared by an arc discharge in a mixed atmosphere of nitrogen and oxygen at a ratio of 8:2, at 2800°C in an argon atmosphere. The amount of refuse such as carbon fragments was reduced in comparison with the case of performing an arc discharge in an atmosphere containing only nitrogen. It was confirmed that similar carbon nanoballoon structures were produced by heating soot prepared by an arc discharge at 2800°C in an argon atmosphere, even if the arc discharge is performed in a nitrogen atmosphere, an oxygen atmosphere, a hydrogen atmosphere, or a mixed atmosphere of one or more gases selected from nitrogen, oxygen, and hydrogen. A test was also conducted on soot prepared by laser irradiation application to carbon while changing the atmosphere. It was confirmed that the same results as for arc discharge were obtained. The same results were also obtained when the inert gas used for heating at a high temperature was changed from argon to helium.

Please replace the paragraph beginning at page 16, line 13, with the following rewritten paragraph:

A carbon nanotube was obtained by an arc discharge using two graphite electrodes containing a metal catalyst. The resulting carbon nanotube was heated at 2800°C for one hour in an argon gas atmosphere using a Tammann furnace. As a result of TEM observation, a change in the structure due to heating was not observed.

Please replace the paragraph beginning at page 17, line 6, with the following rewritten paragraph:

Since the carbon nanoballoon structure according to the present invention can be provided with an opening reaching the hollow portion by oxidation or the like, the carbon nanoballoon structure may be utilized as a capsule. There may be a case where two or more balloons are bonded to form a structure. Such a structure is expected to exhibit excellent ~~electric~~electrical conductivity and reinforcement effects as a filler for composite materials.